The Agricultural College

EXTENSION BULLETIN

Vol. VII. SEPTEMBER, 1911. No. 1

FORMATION OF THE SOIL

By ALFRED VIVIAN, Professor of Agricultural Chemistry,
Author of "The First Principles of Soil Fertility."

"I chatter over stony ways,
In little sharps and trebles,
I bubble into eddying bays,
I babble on the pebbles."

PUBLISHED MONTHLY BY THE OHIO STATE UNIVERSITY
COLUMBUS

Entered as Second-class Matter, November 17, 1905, at the Postoffice at Columbus, Ohio, under Act of Congress, July 16, 1894.

SUMMER.

How well we loved, in Summer solitude
To stroll on lonely ridges far away,
Where beeches, with their boles of Quaker gray,
Murmured at times a sylvan interlude!
We heard each songster warble near her brood,
And from the lowland where the mowers lay
Came now and then faint fragrance from the hay,
That touched the heart to reminiscent mood.
We peered down wooded steeps, and saw the sun
Shining in front, tip all the grapevines wild,
And edge with light the bowlders' lichened groups;
While, deep within the gorge, the tinkling run
Coiled through the hollows with its silvered loops
Down to the waiting river, thousand-isled.

—Lloyd Mifflin.

THE FORMATION OF THE SOIL

By ALFRED VIVIAN.

One could scarcely imagine any subject for discussion more commonplace than that of the soil. Nor could one think of anything which would be less likely to prove interesting to the careless observer. We are accustomed to think of the soil as merely "dirt," a thing to be shunned as far as possible, and kept hidden from sight. Perhaps you will not think the soil worthy of interest and study, but did you ever stop to think that without the soil we could not be living in this world today? The food which you eat could not have been produced if there were no soil, for the plants which make the food for animals, in their

"Underneath all soils are found solid rocks."

turn derive all their nourishment from the soil. So, you see, the soil is after all very important to mankind.

We are so familiar with the soil as it now exists that most of us do not stop to think that it was ever anything different, but it has really taken a long time for Nature to form what we call the soil, and in doing so she has employed the wonderful agencies about which something will be said in this article. Some one has defined the soil as "that portion of the earth at or near the surface, which consists largely of

Since the law requires that Agriculture be taught in the common schools during the coming year, it has been thought best to republish some of the Extension Bulletins which will be most helpful in conducting the work.

A. B. GRAHAM.
Superintendent of Agricultural Extension.

fine particles." And again it has been described as that part of the earth into which the plants send their roots and from which they take much of their food. Well, if the soil is the portion of the earth at the surface, what is below the soil? Most of us know that if we dig down deep into the soil we will come to solid rock. Sometimes rock is reached a few inches below the surface, and again we must dig many feet before we come to it, but sooner or later we are sure to find a bed of stone. We learn therefrom this first interesting fact that underneath all soils are found solid rock.

Now, if we were to examine a sample of soil with a strong magnifying glass or a microscope, we would find that it is largely made up of very fine particles of rock. Mixed with these particles is a much smaller quantity of black material which is called organic matter, or sometimes, humus. A little closer examination will show that the organic matter is simply the remains of plants which have formerly grown upon the land, and which have partially decayed or rotted in the soil. Take a small quantity of a black soil, heat it in the lid of a baking powder can, and see if the odor that comes off is not very much like that we notice on heating bits of leaves in the same way.

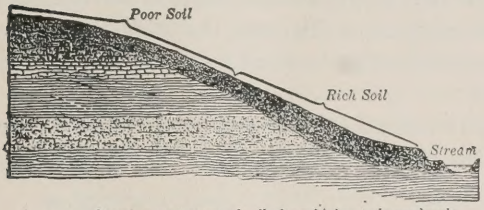
We find then that the soil is composed of small particles of rock mixed with the remains of former plants, and that by far the larger part consists of these rock particles. This suggests the thought that the soil has been formed from the solid rocks such as are found beneath it, and this, indeed, is what the men who have studied the subject have found to be true.

Geology teaches us that at one time all the surface of the earth was solid rock. At that time there was nothing like what we now know as the soil. These rocks contained all the constituents necessary to make a soil and all the substances which the plants use as food with the exception of the element nitrogen. This plant food, however, was not in forms in which the plants could use it. Suppose you had a sack of wheat. You know that there is plenty of food there to nourish you for some time but it is not in a very good form to eat so long as it is in the whole wheat kernel. One of the first things you would do would be to grind it to a flour. And that is one of the first things that Nature does in preparing the food for plants; she grinds the rocks to flour. In other words the first process in the formation of a soil is the pulverization of the rocks.

Nature uses several methods to bring about the grinding or pulverization of the rocks. The first of these is change of temperature, or heat and cold. If we examine a piece of granite we will find that instead of being a simple rock it is composed of different minerals ce-

mented together. Now these minerals are differently affected by heat and cold. We know that most substances expand when heated. The amount of expansion varies for the different minerals in the granite and as a result the effect of change in temperature is to separate the minerals, thus breaking the rock into small pieces.

If we look carefully at any piece of stone we may pick up we



Showing movement of soils from higher to lower levels.

The effect of freezing on rock.

shall find numerous cracks and openings in it. These cracks become filled with water and in the cold weather the water freezes. We know when water turns into ice it expands with great force and consequently when the water in the cracks freezes, it tends to break the stones into pieces. If you have ever known water to freeze in a bottle or jug you

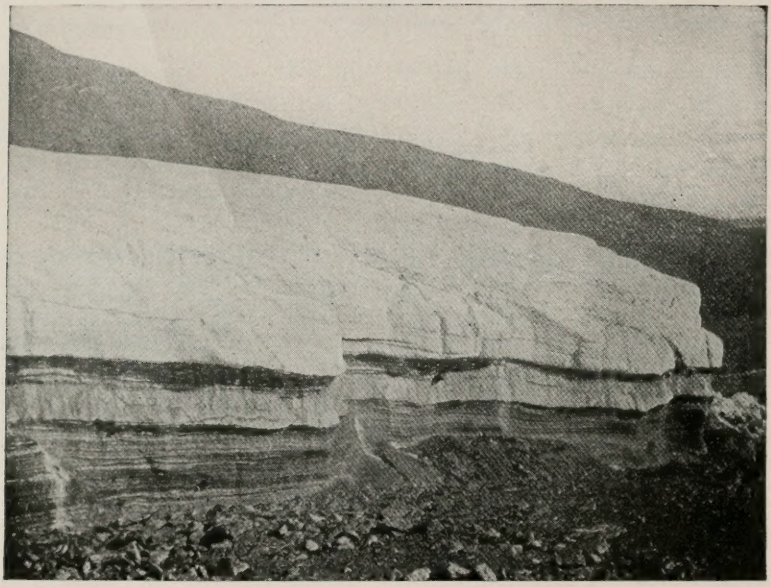
"Running water grinds off the surface of the stones slowly but surely."

know what force it exerts and from this you can see how easy it would be for the ice to break bits of stone off the surface of larger rocks.

More important than either of these factors, however, is the action

of running water. We would hardly think that such a soft substance as water would do much grinding, but water running over stones grinds off the surface slowly but surely. If the stream is swift enough to carry along particles of sand or stone the grinding takes place more rapidly. A rapid mountain stream, for instance, tumbles the boulders along, causing them to rub against each other until they are ground to powder, and at the same time the bed of the stream itself is worn away. In this way deep valleys are sometimes worn into the surface of the earth and the fine material is carried away to form a soil at some other place.

Another agency which helps to grind the rocks is moving ice in the form of glaciers. At one time all of the northern part of our country



The glaciers were important factors in soil formation.

was covered with a thick sheet of ice. This immense glacier pushed its way slowly down from Canada. As it moved south, it carried with it large quantities of rocks, grinding them against each other until they were reduced to particles of various degrees of fineness. Later when the climate became warmer the ice melted and this rock material remained behind to become a part of our soils. So you see there are a number of ways in which the rocks are ground to smaller and smaller fragments until they become as fine as the particles in what is called soil.

But a soil produced by mere grinding of the rock alone is not

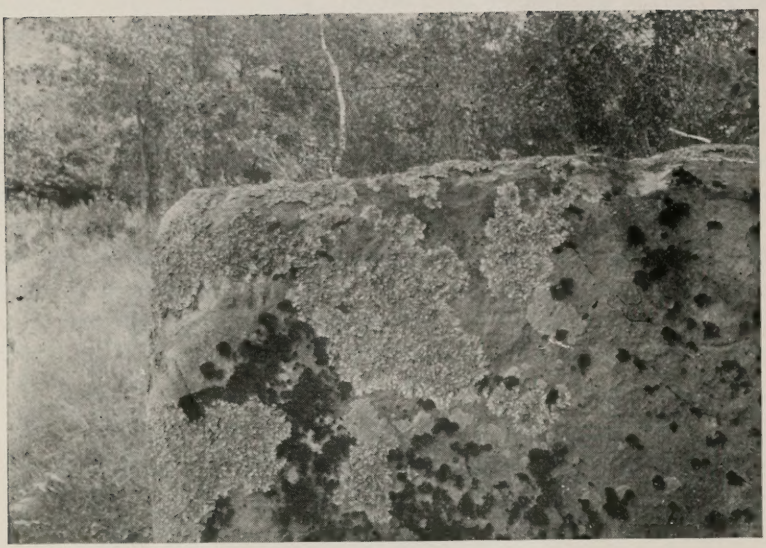
suitable for the growth of farm crops. If you grind your wheat into flour you must still further prepare it before it is fit for food. In the same way the food in the rocks must be prepared for the plants. We say that the food must be made "available" to the plant, or in other words, it must be made soluble so the plants can absorb it through the roots. Water is important in bringing about this change. Pure water will not dissolve much of the rock, but the water which falls on the soil contains carbonic acid gas taken from the atmosphere, and water containing this gas will dissolve much larger quantities of the rock minerals. The oxygen of the air also helps to make the plant food available. You will see, then, that at the same time the rock is being ground its nature is being changed so that it is more readily dissolved.

These processes so far described combine to make the plant food in

Nodules on Soy Bean Roots.

the rocks available, but it has been found that the mineral matter alone cannot support plant life. A soil to be fertile must contain nitrogen as well. All the nitrogen in the soil came originally from the atmosphere. The air is four-fifths nitrogen, but it is in a form in which most plants cannot use it. Before it can serve as a plant food it must be combined with oxygen to make nitrate nitrogen. A little of this is formed in the air during electrical discharges and is carried into the soil by the rain water. This amount, though very small, is probably sufficient to enable plant growth to begin.

Vegetation begins with the very simplest form of plants, such as lichens and mosses, and is, of course, very scanty at first. These plants on dying become a part of the soil, all of the plant nutrients used by them being thus returned. Food that has once been used by plants is



Vegetation begins with very simple forms of plants like lichens and mosses.

very readily made available to succeeding crops through the process of decay. The soil is now able to produce a larger crop, as it contains the plant food in the previous growth in addition to that added through the agencies detailed above. In this way the growth gradually becomes more abundant. The plants upon decaying give rise to humus, and this increases the fertility of the land both by being a source of plant food and by increasing the water-retaining power. Humus is a very important factor in fertility. During the decomposition of the plants, acid substances are formed which act upon the rocks in such a way as to make more of the plant food available. One of the products of decay or fermentation is carbonic acid gas, and this is dissolved in the soil water; this gas-containing water is an important help in disintegrating the rocks.

As the nutritive materials increase from these various causes the lower and simpler forms of plant life are gradually replaced by those which are more highly organized. With the advent of plants, like our common crops, which bear roots other factors in the formation of soils are introduced. The roots secrete an acid substance that has a solvent effect on the mineral matter of the soil, and assist mechanically in breaking down the rocks. All are familiar with the tremendous force exerted by plants in breaking apart rocks and stones if once their tender rootlets obtain a foothold in a crevice. The roots penetrate the soil

sometimes to great depths, and, as they decay after the death of the plant, they leave little channels in the soil which serve to carry down water laden with carbonic acid, as well as to introduce the oxygen of the air, that, in its turn, is a factor in bringing about chemical changes in the soil, which assist in making plant food available.

Sooner or later in the process of soil formation, leguminous plants, such as clover, vetches, lupines, etc., are introduced. If you dig up some of these plants you will find little nodules or tubercles on their roots. These nodules are the homes of numerous bacteria, which enable the plants to derive part of their food from the nitrogen of the atmosphere. This peculiar property of leguminous plants is of great

"Bits of stone are broken off the surface of the large rocks by weathering."

importance, for it is undoubtedly Nature's principal method of increasing the supply of nitrogen in the ground. The nitrogen compounds accumulated by these plants eventually become a part of the soil through their decay, thus adding to its fertility.

It will be readily understood that the various agencies concerned in the formation of the soil do not act separately nor necessarily in any such order as that in which they have been discussed. As a matter of fact all the processes described take place simultaneously. The lower plants do not wait for the rocks to be pulverized, for we see such organisms, as the lichens, growing on rocks from which one would think it

impossible for them to obtain food. If the lichen is removed, grooves or furrows will be found on the surface of the stone, due to the action of the plant. Nor are all soils formed directly from the original rocks, for one of the effects of weathering, etc., is to separate such rocks as the granites into simpler substances, with the result, for example, that huge deposits of limestone are formed in one place, and in another whole hills of sandstone.

The soil is almost constantly moving, for some of the same agencies which form soils are continually carrying them away. Running water grinds the rocks, but at the same time transports the fine par-

Lakes and ponds are gradually filling up, forming muck and peat soils.

ticles to lower levels. It cuts deep valleys in the surface of the earth and carries away the debris, depositing it at various distances from its source. Notice a stream muddied by a recent rain; the mud will be deposited somewhere to help form a soil. The soil is always moving from a higher to a lower level, consequently, it is thinnest at the top of a hill and deepest in the valley. Lakes and ponds are gradually filling up and in time become fertile fields. If the pond is largely filled by the remains of the plants which have grown on it a humus or peaty soil is formed.

The important lesson to be learned from a study of the origin of the soil is, that Nature undisturbed has many ways of adding to the supply of available plant food in the soil. The various forces which

have been under discussion have all tended to change more and more of the food into forms that can be assimilated by the plants so that the amount of vegetation which the soil can produce has been constantly increasing. Under natural conditions this growth is not removed from the ground, but is again made available, so that the land is constantly increasing in fertility. It will thus be seen that the fertility of the virgin soils is the result of accumulations due to a variety of forces acting doubtless through countless ages, a period during which practically nothing has been removed from the soil while much has been added to it.

Nature's method of increasing the humus and soil fertility. Notice the rotten log and the leaves decaying, thus returning plant food to the soil.

Man, on the contrary, has reversed this process and while adding little to the soil has removed much from it. Through the constant harvesting of crops and by leaving the ground bare and exposed to the action of the elements, he is rapidly depleting Nature's store of food and the yield steadily becomes smaller.

This study of the formation of the soil, then, suggests two things that the farmer can do to prevent the exhaustion of the fertility. The first is so to treat the soil as to assist and hasten nature in the process of converting the plant food into available forms by means of good tillage. The second is to return to the soil by means of manure and fertilizers an amount of plant food equivalent to that removed by the crop.

QUESTIONS FOR REVIEWING "FORMATION OF THE SOIL."

1. Of what is soil composed? What can you offer to support your answer? (Seek your answer in the vicinity of your schoolhouse.)

2. What have acted upon rocks to reduce them to very fine particles? What evidence can you offer that rocks have been acted upon by what you have named?

3. Are there any gravel pits or banks in your county? What do these tell concerning soil formation?

4. What is humus? What agencies are soil mixers?

5. Try placing a bottle of water outdoors on a cold winter night. Is there any relation between what happens to the bottle and what takes place on the surface of exposed rocks?

6. Have you ever seen a tree growing in a crack in a rock? What effect did the roots of the tree have on the rock?

7. Perhaps you have found pieces of limestone with marks on them that look like roots. How did these markings come to be on the rock?

8. If there is a low, marshy spot on your farm, dig up some of the dirt and note how it differs from the soils on the higher lands. Why this difference? Is the marsh gradually filling up?

9. Notice the bed of a stream and see if you can explain why some soils are composed of large particles and some of very fine particles.

10. What is meant by "available" plant food?

11. What part do carbonic acid gas and nitrogen play in making plant food?

12. What plan has Nature for transforming nitrogen into available plant food? Produce a specimen showing that Nature has made provision for such work to be done.

13. In what order have low forms of plants succeeded each other in the soil-forming process?

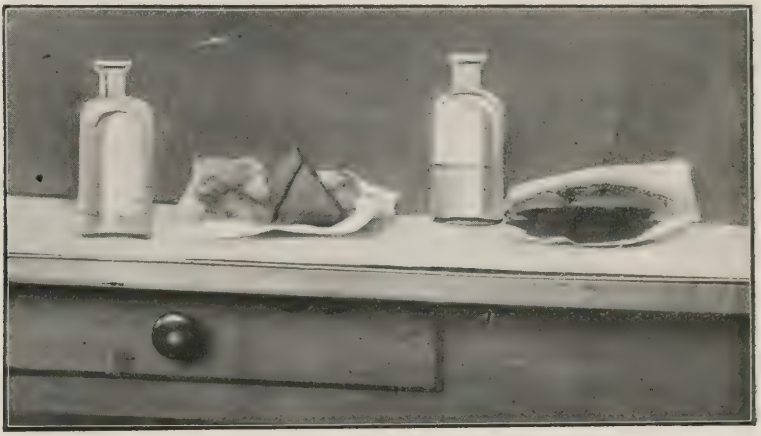
14. How is plant food removed from the soil? How can it be replaced?

15. Careful observations will help one to see year by year soil formation processes. What ones can you cite that are not far from your home or school?

AN ELEMENTARY STUDY OF SOIL.

Probably a knowledge of the simple facts about plants should come first, but we have chosen to make some experiments with soils, because such work can be taken up at this season better than the study of plants. In the course of our suggestions we may ask you to observe what may be silently going on in your own vicinity as to soil formation.

If at your home or in your school you hope to learn about soils, plants, moisture, heat, and air, it will be found necessary to put your



Clay after water it had retained had evaporated. Very hard. Excludes air.

Black soil after water it retained had evaporated. Very loose. Permits air to enter.

question to Nature in form of an experiment and then use your eyes.

1. If a small handful of soil be placed on a pane of glass and rubbed backward and forward across it, a gritting noise will be heard. If the soil has been rubbed hard, it will be found that the glass has been scratched by very hard, small particles which alone would not make soil. What do you think these hard particles are?

2. Place a handful of the same soil in a clean self-sealing fruit jar or a large clear bottle. Fill nearly full of water and shake it well. Let the soil settle and carefully draw off the water through a rubber tube or pour it off very carefully and let what remains dry near a stove. Carefully examine what is left in the can and see where most of the grit or small stones are. What composes the upper layer? Which settled the first, the coarse or fine?

3. Break a rock into small pieces. Put them into some water in a self-sealing jar and shake them well. What do you notice in the lower part of the can? What is sand? How has it been formed?

4. Put into a glass can a little coarse gravel, sand and soil. Add enough water to fill the can nearly full. Shake it thoroughly and let it settle. What is found in the bottom of the can? How have the layers or strata arranged themselves?

5. To show what effect the freezing of water in the crevices or small cracks in stone has, secure a granite stone about ready to crumble. Pour some water on it during freezing weather. After the water has frozen very hard, place the stone where the air is warm enough to thaw. What result has freezing and thawing upon small rocks? What effect has freezing and thawing upon banks or ground plowed in the fall?

6. Freezing and thawing are not alone in affecting rocks. If a piece of iron is placed where air and water may act upon it rust soon appears. Air and water have much the same effect upon all kinds of rock. Through hundreds of years much of this dust would become a part of the soil. Observe fine marble slabs in graveyards. What gas in the air has acted upon this form of limestone? Are there fine particles at the base of the stone? If they can not be seen there, what has become of them?

7. Place a handful of dry sand on a piece of muslin or cheese cloth in a tin funnel and pour a small bottle of water on it. Catch the water in a bottle placed beneath the funnel. Both bottles should be of the same size.

8. On another piece of cheese cloth in a tin funnel put a handful of very black soil. Pour on it the same quantity of water as was used in number 7. Catch the water in a bottle placed beneath the funnel. Which holds the more water, the black soil or the sand? Why?

9. Try the same quantity of clay and the same quantity of water as was used in number 7. Through which did the water run most quickly? The difference between what you poured on the soil and what you caught in the bottle shows what the soil still holds. Evaporation will take that away in time.

10. Place a handful of sand on a piece of sheet iron and put it in the stove on the coals. How much of it will burn? Place a handful of the very blackest soil on the sheet iron and see how much of this soil is left unburned. That which you are not able to burn has been formed of very small particles of rock. That which can be burned is rotten plants and insects. What is humus?

11. Secure some very clean sand. Burn it on a shovel or in an iron pan. Plant a bean or two and see how long it will grow after the food in the cotyledons or half-beans has been used up. What necessary thing has been taken from the soil?

12. Hold a lump of rock salt some distance above a slate or pane of glass. Slowly pour water on the salt and let it fall upon the slate or glass. Allow the water to evaporate. What remains on the slate? This shows how rocks are being worn off and partly prepared to supply plant food gradually.

13. Dig up a garden bean or pea (do not pull it up) and wash the dirt from the roots. Observe the nodules, the nitrogen converters. Grow a garden bean in a box containing dirt to see if nodules will be formed.

14. Plant a few large seeds in a box having a marble or limestone slab for a bottom. The seeds should be placed on the slab and the plant should be grown to maturity. See if you can find root markings on the marble or limestone. A. B.G.

AGRICULTURAL ARITHMETIC.

1. If six pecks of wheat are sown on one acre, how much seed wheat will be required for a field 40 rods long and 25 rods wide?

2. If sixteen four-inch tile are required for a rod, how many tile will be needed for a ditch a mile and a quarter long?

3. The wagon and wheat weigh 5530 pounds. The wagon alone weighs 1300 pounds. What is the wheat worth at 88 cents per bushel?

4. A row of corn shocks takes up a space twice the width of the space between two rows of corn. The length of the space is 40 rods. How much ground is occupied by the shock row?

5. There are 210 rows of corn on the long side of a field and 120 on the short side. What will the cutting cost at 5 cents for each shock 10 hills square?

6. At $28 per ton for commercial fertilizer, what will it cost to fertilize a field 40 by 60 rods if 250 pounds are used on each acre?

7. One-half ton of lime per acre was sowed on a field 35 rods long and 25 rods wide. How many tons of lime were used?

8. It costs $1\frac{1}{2}$ cents per bushel for threshing oats and $2\frac{1}{2}$ cents for wheat. What will the threshing of 1850 bushels of oats and 280 bushels of wheat cost?

9. A field is a half mile long and a quarter of a mile wide; if two and a fourth acres are plowed each day, how many days will be required to plow it?

10. A man hauls to a creamery 1980 pounds of milk at one trip. What does he receive at 15 cents per hundred?

11. If eight pecks of wheat are sowed on each acre, how many bushels will be required for eighteen acres? Is eight pecks the usual quantity of wheat sowed on each acre? How does the farmer regulate the amount sowed?

12. After peeling eight pounds four ounces of potatoes it was

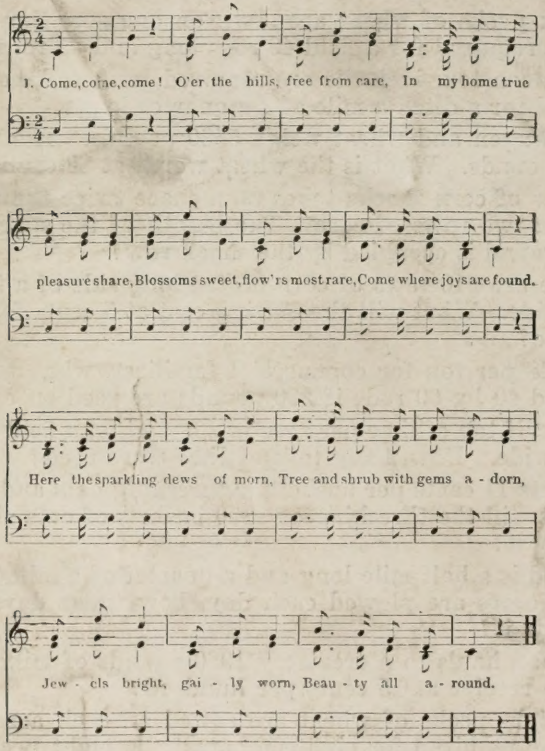
found that the peeling weighed two pounds and twelve ounces. What per cent was lost? If you think the per cent of potato peeled away is too high, weigh a few potatoes and then weigh the peelings. You may be surprised.

13. When 33⅓ per cent of potatoes is waste, what is the value of sixty pounds of peeled potatoes if 80 cents per bushel is the purchase price? Is 80 cents a fair market price at present?

14. A grain harvester which cost $125 was used for seven seasons; $25 were spent for repairs; it was valued at $10 in trade for a new one. What was the cost per season? Is $125 a reasonable price for a grain harvester? With fair care how many seasons will such a machine last? The number of seasons would depend much upon the acreage cut.

5. If the average cost per season for a grain harvester is $22.50, what is the cost per day if it is in actual use only fifteen days? Are fifteen days too few for the actual use per season on a farm of eighty or one hundred acres? A. B. G.

THE INVITATION.



Come, come, come!
Not a sigh, not a tear,
E'er is found in sadness here,
Music soft, breathing near,
Charms away each care.

Birds in joyous hours, among
Hill and dale, with grateful song,
Dearest strains here prolong,
Vocal all the air.